Energy Foundation Funded Research Project

Research of Policies to Guarantee Large-Scale Renewable Energy Development and Grid Integration in China

Executive Summary

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Renewable energy industry has undergone rapid development in recent years in China, especially wind power generation and solar energy industry. The installed capacity of wind power generation has doubled for four years successively since 2006, and solar power generation has started as well. In addition, connected-grid photovoltaic market was launched in 2009, and solar photovoltaic industry and water heater manufacturing industry have ranked among the first in the world. Chinese government has put forth new objectives for renewable-energy power generation, and the objectives for installed capacity of wind power generation in 2020 will be increased from the 30 million KW determined in 2007 to 150 million KW, while those for the installed capacity of solar power generation in 2020 has been drastically increased from the previous planned 1.8 million KW to 20 million KW. Therefore, the state formulated planning for 7 ten-million KW wind power generation bases and several million KW wind power generation bases at the end of 2008, and the solar power generation bases are being planned as well. Such wind power generation and solar power generation bases are mainly concentrated in “three norths”(the northeast, the central north, and the northwest) areas with rich wind energy and solar energy resources.

However, renewable energy power generation such as wind power generation and solar energy power generation etc. is generally random and intermittent with low capacity coefficient, and the areas with favorable wind power and solar resources in China are generally located in remote areas far away from the power load centers and artery grids. Therefore, such large-scaled and concentrated development of wind power generation and solar power generation depends on high-voltage long-distance means of power transmission. In addition to large-scaled construction of power routes, the structural peak-adjusting capacity inside the electric grids shall be improved, which has brought about unprecedented technical and management challenges to the safe and stable operation of the electric grids of the local areas and the even the whole region. As the total installed capacity of wind power generation expands in recent years, the problems on grid connection of wind power generation and absorption of wind power generation by the electric grids have gradually appeared, especially in regional areas such as the northeast etc.. Thus guaranteeing large-scaled renewable power generation and grid connection has become an important task for future large-scaled development and utilization of renewable energy.

The research has made in-depth analysis of the policy environment of and the problems confronting the national renewable energy development and put forth corresponding policy proposals on grid connection of renewable energy according to the objectives and tasks of renewable-energy power generation before 2020 in China based on making reference to the domestic and foreign practice in formulation of policies promoting grid connection of renewable energy and the experience obtained during implementation thereof.

The contents of research subject on Guarantee policy for the large-scaled renewable energy power generation and grid connection can be divided into the following 4 parts:

1. Comments on Current Policies for Renewable Energy Power Generation and Grid Connection and the Implementation Effect

1.1 Summary and Analysis of Relevant Current Policies on Renewable Energy Power Generation

China has preliminarily established a policy framework supporting renewable energy power

generation, and has achieved certain effects through years of implementation. The major policies include priority on-grid policy for power generation, classified power price policy, expenses amortization policy, electric grid constructions subsidy policy and power generation quota policy etc.

1.1.1 Priority On-Grid Policy for Renewable Energy Power Generation

Thanks to the state preferential power price policy and compulsory grid connection policy for renewable energy power generation, the economic and system barriers of renewable energy power generation and grid connection were basically removed after 2006, and wind power generation has taken on the momentum of scaled development, while the market for solar power generation and power generation with agricultural and forestry wastes has just started. Though due to various construction cycles(The construction cycle of wind farms is short, and construction of wind farm can be completed within merely several months if wind power generators can be supplied in time and go through relevant formalities smoothly, while the construction cycle of electric grid is relatively longer.), grid connection of the wind power generating units on some wind farms has been delayed for some time. Nevertheless, generally speaking, provisions on renewable energy grid connection in the legal and policy system have granted social responsibilities and pressures to electric grid enterprises and cause them to make efforts to absorb renewable-energy power in technical and operational management and substantially increased investment and construction for grid connection. As the installed capacity of wind power generation keeps on expanding, electric grid enterprises have started to regard wind power generation as a power source that must be considered during electric grid layout and planning, and wind power generation has been incorporated into power dispatching, power balance and power industrial statistics since 2008. To conclude, priority grid connection of wind power generation has been basically guaranteed, and the compulsory on-grid system have been basically implemented effectively since 2006.

1.1.2 Classified Power Price of Renewable-Energy Power Generation

The National Development and Reform Commission promulgated “Proposed Methods for Management of Renewable Energy Power Price and Expenses Amortization” in January 2006, and the principles for determining wind power price therein are as follows: government guided price is implemented for the on-grid power price of wind power generation projects, and the power price standards shall be determined by the price authority of the State Council according to the price formed through bid invitation. As required by the file, some provinces(cities and regions) such as Inner Mongolia, Jilin, Gansu and Fujian etc. organized bidding for several provincial franchised wind power generation projects after 2006, and reported them to the National Development and Reform Commission for authorization. In addition, the National Development and Reform Commission has preliminarily determined the authorized power prices for the wind power generating projects in some provinces through referring to the bid-winning power price. And most of the other provinces(cities and regions) still follow the practice of authorizing power price for each project one by one. Some particular province such as Guangdong Province adopts fixed power price policy, and has made out the provincial lever power price for the wind power generating projects. Therefore, bidding power price, fixed power price and authorized power price coexisted in wind power price policies from 2006 to July 2009 in China.

1.1.3 Expenses Amortization Mechanism for Renewable Energy

The National Development and Reform Commission launched allocation work for renewable energy power price surcharge of 2006 in May 2007, and checked the data submitted by various provincial electric grids and renewable energy power generating enterprises. And the National Development and Reform Commission promulgated "2006 Renewable Energy Power Price Subsidy and Quota Transaction Program" in September 2007, and 38 wind power generating, biomass power generating and solar power generating projects won a total subsidy of 251.46 million yuan.. And the commission promulgated "Renewable Energy Power Price Subsidy and Quota Transaction Program for January-September 2007" in March 2008, and 75 wind power generating, biomass power generating and solar power generating projects won a total subsidy of 699.37 million yuan. In addition, the commission promulgated "Renewable Energy Power Price Subsidy and Quota Transaction Program for September 2007 to June 2008" in November 2008, and 151 wind power generating, biomass power generating and solar power generating projects won a total subsidy of 1,266.93 million yuan, while 224 wind power generating, biomass power generating and solar power generating projects won a total subsidy of 1,851.88 million yuan in the "Renewable Energy Power Price Subsidy and Quota Transaction Program for July to December 2008" promulgated in June 2009. And 281 wind power generating, biomass power generating and solar power generating projects won a total subsidy of 2,986.89 million yuan in the "Renewable Energy Power Price Subsidy and Quota Transaction Program for January to June 2009" promulgated in December 2009

1.1.4 Renewable-Energy Electric Grid Construction Subsidy

The National Development and Reform Commission definitely put forth the subsidy standards for grid connection expenses in [2007] No. 44 file at the beginning of 2007, i.e. the grid connection expense of renewable energy power generating projects refers to the investment on power transmission and transformation and operational and maintenance expenses incurred for renewable energy power generating projects. The grid-connection expenses standards are formulated according to the route length: 1 fen per KWh within 50 Km, 2 fen per KWh for 50-100 km, and 3 fen per KWh for 100 km and above. The practical reason for the compensation standards generally deemed to be slightly low inside the industry is that the current compensation standards have only considered the recovery of the electric grid and route investment for grid connection of new renewable energy power generating projects such as wind power generation etc. , i.e. the compensation for the investment on connecting the wind farm into the current grid connecting system of the artery electrical grid, while recovery of the investment on ultrahigh voltage and extra-high voltage circuits and compensation for peak adjustment in other power generating units have not been taken into consideration. From the perspective of recovering the grid connection investment, the current compensation standards can roughly reflect the practical demands for funds.

1.1.5 Renewable-Energy Power Generation Quota

Compared with the foreign power system, Chinese power system has its particularity. The most obvious difference therein is that a fully market-oriented and competitive power market(including all the links such as power generation, power transmission, power distribution and power consumption) has been established in countries and regions such as America, Australia and Europe etc.. Therefore they have Imposed quota obligations on the regional public power enterprises in charge of power distribution and sales, and realize the quota through the freely competing power distribution and sales enterprises. However, China is still undergoing power

system reform, and from the perspective of the industrial structure and organ establishment, power transmission, power distribution and sales are in the charge of electric grid enterprise. From the perspective of the regional layout, currently there are only two electric grids such as south grid and state grid and west Mongolia independent grid which are not mutually overlapped. In addition, as two state-owned enterprises, the state grid and south grid will carry out means of implementation greatly different from foreign ones even if compulsory quota is distributed to them. Due to lack of specific operational measures, punishment and rewarding measures in China, quota has not been practically implemented. However, the establishment of compulsory market share objective for non-hydraulic renewable energy power generation in "Medium and Long-Term Development Planning for Renewable Energy" is really one of the main reason why many wind power developers, especially large-scaled state-owned power source enterprises, have rivaled with each other to occupy wind power generation market in recent years, while the "guaranteed purchase in full" system put forth in the draft of "Renewable Energy Law"(Amended Version) has formed real pressure on the electric grid enterprises, which can also be regarded as the unique means of implementation of the compulsory quota policy in China.

1.2 Comments on Implementation of the Current Renewable-Energy Power Generation and Grid Connection Policies

1.2.1 Implementation Effects of Renewable -Energy Power Generation Policies

The emphasis in the current policy support for renewable- energy development is placed on the renewable-energy equipment manufacturing industry and market development. The powerful supports with obvious effects for the manufacturing industry are subsidy offered to wind power generating units with own intellectual property rights, and the demand that franchised wind power generating projects shall guarantee equipment localization rate of 70%(The policy was implemented since 2003 and was revoked in 2009.) etc., and the power support with obvious effects for market development are on-grid power price policy and tax preferential policy. However, little consideration has been given to grid connection policy for renewable energy power in the current policy system. Even if in-depth analysis of the current grid connection policy for renewable energy power has been made, it can been seen that almost all of these policies have required the electric grid enterprises to provide service and purchase wind power in full from the perspective of the renewable energy power developing enterprises instead of considering how to formulate policies from the perspective of the electric grid enterprise or the whole power system. Renewable energy power generation policies shall be gradually adjusted and perfected according to the demands for development of renewable energy. And it is better to make preparation in advance thereto. At present, Chinese wind power generation industry and solar power generation industry etc. have grown up, and the power price, investment and tax policies have been basically available, thus renewable energy power transmission and market absorption shall be the emphasis in policy support.

1.2.2 Characteristics and Problems of Policies on Renewable Energy Power Generation and Grid Connection

(1) As for grid-connection policy for renewable energy, there are two obvious characteristics in providing for responsibilities and means of implementation: Firstly, emphasize purchase in full, which is almost unconditional. Secondly, emphasize qualitative corporate responsibilities and lack

quantitative indexes, definite restriction for the electric grid and fail to put forth policy on the task that must be fulfilled, or the that can activate the initiative of the electric grids to a greater extent. “Purchase in full” and lack of quantitative “corporate responsibilities” lead to the situation that whether to absorb renewable energy power, how to absorb and how much renewable energy power to be absorbed depend on the self-consciousness and sense of responsibility of the electric grid enterprises to a certain extent.

（2）The current grid-connection policy merely takes part of the power system into consideration instead of making overall systematic arrangement on how to absorb renewable energy power from the perspective of the whole power system. For example, as for the economic policy, the scope of incentive and subsidy measures is narrow. At present, the subsidy level for grid connection merely consider the incentive and compensation for absorption of renewable energy power through local and provincial grid connection instead of the incentive and compensation for the investment on absorption of relevant electric grids by the provincial and regional markets. In addition, compensation for peak adjustment towards intermittent renewable power such as wind power generation and solar power generation on the part of other kinds of power generating units.

（3）More often than not, the current grid connection policy puts forth restrictive requirements for electric grids instead of the renewable power generating market on the power source side. For example, there is no suitable state technical standards for grid connection of renewable energy power now, which leads to lack of power for driving the renewable-energy power generating equipment manufacturers to develop and manufacture power generating units that meet the requirements of the electric grids. In addition, lack of provision on predicting the output power of the renewable energy power generating farms leads to the situation that the electric grid enterprises have no right to require the renewable energy power generating farm to make prediction on the output power, and that the electric grids lack definite power to do so, and such issues shall be standardized through rational policies.

（4）The current quota policy only puts forth the long-term objectives and fails to put out specific detailed implementation rules.

2. Difficulties and Challenges for Future Large-Scaled Grid Connection of Renewable-Energy Power

2.1 The power features of wind power generation influence operation of power system.

As for technical perspectives, the random fluctuations of wind power generation have certain influence on the operation of power system.

- **Influences on Voltage Level of Electric Grids:** Long-distance transmission of a large amount of wind power in China will generally lead to excessively large voltage drop in the circuits, and influences on the voltage stabilities and decrease in stability in regional electric grids. In addition, the voltage stability limit of the electric grids have also restricted the maximum installed capacity of the wind farms. To conclude, the capacity of absorbing wind power generation of the electric grid is generally unable to comply with the development of wind power planning and the capacity of the wind farm absorbed thereto is restricted by the own conditions of the electric grids in case of no well-coordinated development between electric grid planning and wind power planning.

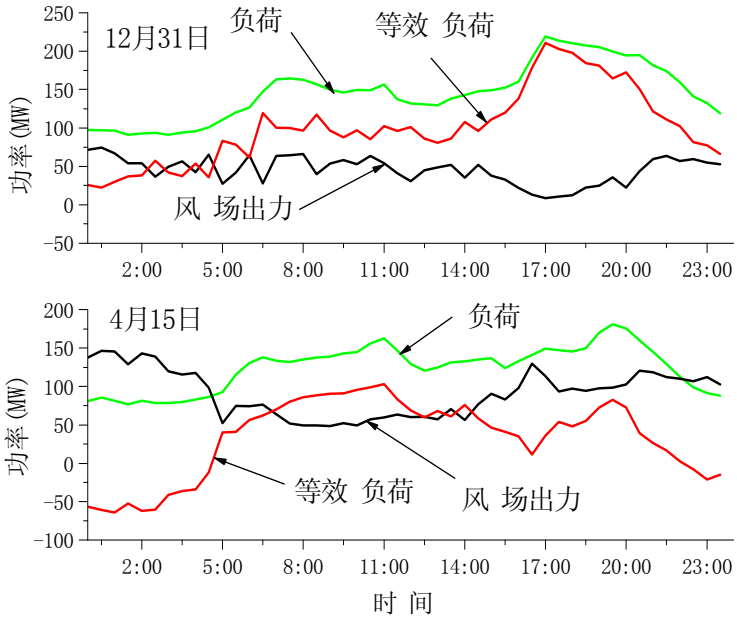
- **Influences on the level of short-circuit current of the electric grid:** The equipment such as buses and switches of the nearby power transformation stations shall be replaced, and the circuit breaking capacity of the switches shall be increased after grid connection of the wind farm of a large installed capacity. In addition, the short-circuit currents at various observation points in various short-circuit positions vary from each other in case of full-load power generation on the wind farm. And the short-circuit currents provided by the wind farm decrease when the distance between the short-circuit points and the wind farm. Meanwhile, the short-circuit currents provided by the wind farm always account for a high proportion, even in case of circuit breaking near the wind farm.

- **Influences on the power quality of the electric grids:** Due to the random fluctuations of wind speeds, and the influences by the turbulences, wake effect and tower shade effect during operation of the wind power generating units, the output power of the on-grid wind power generating units, and then the quality problems such as voltage fluctuations and flicker etc. in the electric grid. And the extensive use of power electronic frequency converting equipment in the variable speed wind power generating units will cause problems such as harmonic waves and indirect harmonic waves.

- **Influences on stability of electric grids:** The temporary stability and frequency stability will change after grid connection of the wind power generation. And voltage stability after grid connection of the wind power will generally only involve the electric grid connected with wind power generation without causing great influences on the voltage stability of the artery electric grids. In addition, the operational features and the capacity of stable operation of the wind power generating units will determine the voltage stability of the regional electric grids to a great extent. And as for independent electric grids, due attention shall be paid to the frequency stability of the electric grid in case of excessive high proportion of the wind power generation.

2.2 The power features of the wind power generation has expanded the peak-valley difference of equivalent load.

The random fluctuations of wind power generation have caused great influences on the system load and peak-valley changes. Adopting other power sources for peak adjustment of the electric grid will increase the difficulty in system dispatching and operational cost of the system. According to load features and wind energy resources in north China, the peak-valley difference of equivalent load formed by the output power and load in most of the areas have increased. The figure 2-1 shows the practical survey curves of load and output power of wind farm on two typical days(December 31 and April 15) during wind season in winter and spring in Baicheng area, Jilin Province of China. As shown in the figure, the output power is contrary to the load trends of the wind farms in most of the periods. Peak load involves small output power of the wind farm, while valley load indicated large output power of the wind farm. The output power of the wind farms in Baicheng area cannot improve the load features of the system. On the contrary, it has worsened the load features of the system. Grid connection of wind power generation has increased the peak-valley difference of the equivalent load and the difficulty in electric grid dispatching.



Power(MW) December 31 Load Equivalent Load

Output Power of Wind Farm

Power(MW) April 15, Load

Equivalent Load, Output Power of Wind Farm

Figure 2-1 Equivalent Load Curves on Relevance between Daily Load Changes and Output Power of Wind Farms in Baicheng Area, Jilin Province

2.3 Structure of power source influences the peak-adjusting capacity of the electric grids.

At present, there is a great peak-valley difference in north China, with the minimum load rate being around 0.6 and even nearly 0.5 in some areas. The large peak-valley difference has caused great difficulties to peak adjustment. And sufficient coal-fired power generating units must be put into operation to meet the demands for the daytime peak loads. And the output power of the coal-fired power generating units is lowered during nighttime valley load period. And the decrease in the output value of the coal-fired power generating units, i.e. peak-adjusting capacity, shall be the peak-valley load difference plus output power of wind power generation to guarantee purchase of wind power in full. Strong winds frequently occur during nighttime low load period in areas of large-scaled grid connection of wind power generation in north China, for example, northeast electric grid and Inner Mongolia electric grid, leading to obviously insufficient peak-adjusting capacity in case of large-scaled grid connection of wind power generation and restriction over output power of wind power generation.

In addition, the downward adjustment of the output power of the thermal-power combined power generating units in north China is also restricted by the demands for thermal load. The output power of the thermal-power combined power generating units shall not be decreased during nighttime low-load period to guarantee demands for heat supply during heat supply season in winter.

And the nighttime output power of wind power generation is large in north China, and is small during peak load periods, which has increased the difficulty in peak adjustment in the electric grids.

Wind power generation may compete for market against coal power generation in case of insufficient power load. If the average annual power generating hours of the thermal power generating units is lower than 5,000 hours in areas of large-scaled grid connection of wind power generation, such is a serious waste of the capital construction funds of the state. Therefore it is necessary to find out an overall solution to the uniform planning of wind power generation and thermal power generation in addition to taking peak-adjustment of the power source into consideration to solve the relevant issues on the large-scaled grid connection of the wind power generation.

2.4 Development of wind power generation is confronted with large-scaled long-distance power transmission.

At present, the electric grids connected with wind power generation of China are characteristic of large scale, high concentration, long distance and high voltage.

- The capacity of individual wind farms has increased. Several wind farms with an installed capacity of over 100,000 KW have been put into use in China, and a lot of wind farms of an installed capacity of several hundreds of thousand KW are being planned and constructed. According to the development objectives formulated by the National Development and Reform Commission, ten-million KW wind power generating bases are planned to be built in Hebei, Jiangsu, Inner Mongolia, Gansu and Xinjiang etc.. The construction and grid connection of the extraordinarily large-scaled and ultra-high capacity wind power generating bases is also a first in the world.

- The voltage level for connecting the wind farms in the electric grid is higher, and the previous multiple-access power distribution grids have developed into direct access power transmission network. At present, several wind farms being built and planned in China are directly connected with 220KV power transmission grid. 330KV-750KV connection program is adopted for ten million KW wind power generation bases in Gansu. See Figure 2-2:

Anxi Wind Power Generation 2,100 MW **Yumen Wind Power Generation 1,260MW**

750KW Grid Framework

Figure 2-2 Grid Connection of 3,360MW Wind Power Generation into Electric Grid in Gansu

There are certain restrictive factors for effectively exercising the maximum efficiency and economic advantages of some ultra-high voltage projects before the ultra-high voltage electric grid framework is completely formed, mainly including: long-distance(larger than 400Kv) transmission capacity of the electric source base is restricted by the temporary stability; High compensation and high resistance required for restricting over voltage conflict with the demands for capacity and powerless compensation in transmission of large powers, and the voltage supporting capacity in long-distance power transmission passages is relatively insufficient. And the voltage stability in the recipient electric grid with a high proportion of power acceptance tends to become more serious.

2.5 Outstanding Problems in Absorption of Wind Power in Regional Electric Grids

The current mode of wind power development of China is “constructing large bases, and connecting into large electric grids”. There are rich and concentrated wind energy resources in Xinjiang, Inner Mongolia and Gansu etc.. However, the planned ten-million KW wind power generation bases are far away from the load center, and large-scaled wind power generation cannot be absorbed in local areas, and shall be transmitted to the load centers through long-distance power transmission via transmission grids to be absorbed in a larger scope, which is the main issue related to coordinated between the current electric grid planning and development of wind power generation in China.

Wind power generation is mainly developed on land in China before 2020. The million KW and ten-million KW bases to be laid out in China involve provinces and autonomous regions such as Inner Mongolia, Gansu, Xinjiang, Hebei, Jiangsu and Jilin etc.. According to the wind power absorptive markets, the aforesaid provinces(regions) can be roughly divided into three categories:

Jiangsu is a load center of China, and the coordinated development of wind power, other electric power sources and grids can be realized through suitable allocation of peak-adjusting power sources and strengthening electric grid construction, which can basically meet the requirements for local absorption of wind power generation.

Provinces and regions such as Inner Mongolia, Hebei and Jinlin etc. have limited capacity of wind power absorption, and wind power can be transmitted to the nearby load centers such as Liaoning, Beijing, Tianjin, Tangshan and Shandong etc. through strengthening trans-provincial(regional) interconnection of electric grids inside the regional electric grids to realize absorption of wind power in the regional electric grids.

Gansu and Xinjiang have low capacity of wind power absorption. In the long run, the capacity of wind power absorption of the whole northwest electric grid is also relative limited. Therefore, wind power in northwest must be sent to load centers such as central China and east China etc. for absorption, and absorption of wind power in the northwest is mainly characteristic of long distance and large-scaled outward transmission.

Large-scaled outward transmission of wind power is the main way to solve wind power absorption in “three norths” areas of China. The wind power output power will have to be reduced due to insufficient demands for load before the absorption of wind power is solved. The coordination between electric grid planning and the development of wind power involves grid connection between large regions, and is related to the medium and long-term planning and electric grid layout. Construction of long-distance transmission grids for wind power involves huge

demands for funds, and a high cost in the access grid, therefore it demands support from the state policies.

2.6 Weak Technical Supporting System

At present, most of the technical standards and regulations for wind farm access systems in various countries worldwide require wind farms or wind power generating units to have dynamic powerless adjusting capacity, climbing capacity for tracking the preset value of active power, active adjusting capacity and low-voltage transverse capacity on special occasions of the electric grids. Especially, these functions are quite important for smooth grid connection of wind power into electric grids of a high proportion of wind power. However, most of the current wind power products of China do not have such capacity mainly because there is lack of technical standards, and the manufacturers of wind power generating units do not have pressure in this respect, and lacks power to increase cost and manufacture wind power generating products of higher properties and more friendly to electric grids. China is still in the initial phase of scaled development of wind power, and formulation and research of relevant indexes in the technical standards and regulations for grid connection of wind power still lag behind. Worse still, dynamic powerless controlling techniques, active power controlling techniques and low-voltage transverse techniques of the wind power generating units are mostly monopolized by foreign companies, which has increased the manufacturing cost of domestic wind power generating units.

2.7 Imperfect Development of Power Market

China has not achieved mature development in power market, and fails to obtain perfect market modes. In addition, there is lack of basic functions such as optimized resources allocation in the market, technical progress, interest distribution and micro balance etc.. Especially, no reasonable renewable-energy power price mechanism has formed in China, which has influenced healthy and sustainable development of the industry. The current power price system has not reflected the power energy quality and real-time market value of various power generating projects, and the expenses amortizing system has not compensated the cost of power dispatching. Therefore, cost and risk sharing and market competition will necessarily occur in electric grid construction and power dispatching between large-scaled wind power generation and conventional power system.

The entry management system for investment on wind power generation projects and connected-grid power generation management system are monotonous, and have laid biased emphasis on large-scaled wind power generating projects with weak support and guarantee for the flexible and scattered medium and small-scaled wind power generating projects, which is adverse to full and high-efficient utilization of wind energy resources and has increased the pressure on long-scaled grid connection of wind power and dispatching thereof.

3. Analysis of Foreign Guarantee Measures for Large-Scaled Grid Connection of Renewable Power Generation

3.1 Current Situation of Foreign Power System and Grid Connection of Wind Power

Current Situation and Problems of Grid Connection of Wind Power in Europe

By the end of 2008, the accumulated installed capacity of wind power generation in the whole Europe was 65,946,000 KW, including 64.95 million KW for European Union, which has met 4% of the power demands. Germany, Belgium, England, Denmark, Holland, Belgium and France have developed marine wind farms.

The accumulated installed capacity of wind power in Germany was 23.90 million KW at the end of 2008, ranking the first in Europe. And that of Denmark was 3.18 million KW, and is the country of the highest proportion of installed capacity of wind power in the world. However, as for the current proportion of the installed capacity, the major problem confronting the electric grid in the European Union is transmission capacity of the electric grids instead of the peak adjustment.

Current Situation and Problems in Grid Connection of Wind Power Generation in America

According to the report issued by AWEA, the total proportion of the installed capacity of wind power generation and natural-gas power generation in the newly-added installed capacity of power generation of America among the total installed capacity of power generation in 2008, and the installed capacity of wind power generation accounts for about 42%.

By the end of 2008, the accumulated installed capacity of wind power generation of America was 25.17 million KW, ranking the 1st worldwide, and wind power generation has supplied 1% of the power demands. And 4.45 million KW wind power generating projects are being built. According to the data issued by AWEA, the accumulated installed capacity of Texas is 7.12 million KW, ranking the 1st in America, and 1.65 million KW projects are being built. According to the statistical data of AWEA, the proportion of the wind power in power sales of some of the power companies has exceeded 10%.

The availability of and power demands for wind energy resources are not well-matched in geological locations in America, or positively relevant to the time to use the wind energy. Only 7% of the populations reside in the top ten states with large potentials of wind energy resources in America, and the peak output power of wind power generation generally occur in the periods with low demands for power load in most of the current areas of rich megawatt wind energy resources.

3.2 Foreign Medium and Long-Term Development Planning for Wind Power Generation and Guarantee Measures for Electric Grids

(1) Medium and Long-Term Development Planning of European Union

The total installed capacity of wind power generation of the 27 countries in EU reached 64,948 MW in 2008, and has met 4% of the power demands. European Commission estimates that 34% of the power demands of EU will be supplied by renewable energy power generation, including 12%

of the power demands to be supplied by wind power generation. TPWind, wind energy technical platform of Europe, has also put forth the development objectives, i.e. wind energy will become the primary substitution energy of Europe in 2030, and the accumulated installed capacity will reach 300 million KW, 50% of which is marine wind power generation, and repowering projects of 7.5 million KW will be constructed. In addition, 25% of the power consumption in Europe will be supplied by wind power.

(2) Incentive Policies for Electric Grid Construction of EU

As provided for in paragraph 1 of Art. 16 of "2009 Order for Promoting Renewable Energy Power Generation", the member countries of EU may take suitable steps to speed up authorization procedures for grid infrastructures, and coordinate and approve grid infrastructure construction projects through administrative and planning procedures. According to paragraph 3, the operational expenses such as electric grid connection, electric grid upgrading and expansion, and improvement of electric grid etc. shall be jointly shared by the power manufacturers, power system transmission operators and power system distribution operators etc.. However, the sharing system shall be based on objective, transparent and non-discriminative standards.

1）Development Planning and Guarantee Measures for Wind Power Generation in America

It is estimated the installed capacities of wind power generation in 2010, 2015 and 2020 will reach 30 million KW, 36 million KW and 48 million KW respectively under the framework of 2009 renewable energy law of Germany. And the main growth in the installed capacity of wind power generation in Germany after 2010 comes from development of marine wind farms. The development scale of marine wind farms in 2015 and 2020 will reach 9.80 million KW and 20.40 million KW respectively, which are mainly concentrated in development of marine wind power generation on North Sea and Baltic Sea.

Relevant organs estimate that the development scale of renewable energy in 2015 will reach 47.30 million KW, and then 20% of the power supply will come from renewable energy in the generated electric quantities of the whole Germany, while wind power generation will account for 12.7% of the total generated electric quantities. So high proportion of wind power generation means the changes in energy flows and the potential bottleneck in power transmission routes. According to planning of Germany, 850km 380KW power transmission routes will be newly built in Germany by 2015.

In addition, Germany has determined to adjust peak of wind power generation by means of improving the technical capacity of predicting wind power and energy storage through water pumping so as to guarantee stable grid connection and transmission of wind power generation.

2）Supporting Policies in Denmark

According to provisions made by Danish government, cost amortizing policy for grid connection is implemented for wind power generation, i.e. the expenses for construction of transmission routes and transformation stations for grid connection of wind power will be jointly shared by the power company and the owner of the wind power generating units. And the expenses for the wind power generating units installed on the land, low-voltage circuits, and power transformation stations in the locality of the wind farms, and the construction and maintenance

expenses of the transmission routes will be undertaken by the owner of the wind power generating units. As for the wind farm projects(with the minimum installed capacity of 1.5MW) constructed under government guidance, the expenses for increasing the capacity of the supplementary electric grid will be undertaken by the electric grid company. As for the marine wind power generating projects incorporated into the wind power resources development planning of Denmark, the expenses for connecting the wind power generating units and the land electric grid will be wholly borne by the electric grid company. As to the project that has not been listed in the planning, the construction and maintenance expenses for the supplementary electric grids of the projects will be undertaken by the owner on its own.

As definitely pointed out in the 2nd and 3rd sentences of paragraph 1 of Art. 30 in Part IV of the "Law for Promoting Renewable Energy"(No. 1392 Bill dated December 27, 2008), the owner of the wind power generating units may use the means of connecting with land electric grids, and the marine connection has been established by the power supply company. The power company takes charge of providing guidance and paying expenses. How to distribute the expenses for establishing electric grid and connection with electric grid between the owner of the wind power generating units and the comprehensive power supply company is determined by the minister of the Ministry of Climate and Energy.

In addition, as provided for in the energy prospect policy of Denmark in 2025, the power price will be increased by about 0.03 Euro per KWh for each 100 million Danish Krona used in the construction of new transmission routes.

（3）Development Planning for Wind Power Generation in 2030 of America

According to the plan issued by American Ministry of Energy in May 2008, the installed capacity of wind power generation in 2030 shall reach 300 million KW, which will reach the objective of meeting 20% of the power demands of America.

(4) Incentive Policy for Electric Grid Construction of America

As provided for in Art. 301 of "American Recovery and Reinvestment Act", the Ministry of Finance is obligated to provide loan of an accumulated total amount of no more than 3,250 million USD for at least one power transmission route and relevant equipment, construction, financing, promotion, planning, operation, maintenance or investigation during construction or reconstruction of the project located within the service scope of the western power administration bureau.". According to Art. 405, the Ministry of Finance shall provide financial support in the amount of no more than 50% of the project funds for the advanced electric grid technical model project. And according to Art. 1705, the Ministry of Finance shall provide security for the power transmission system started before September 30(including), 2011, including upgrading projects.

3.3 Summary of Experience in Adaptation to the Large-Scaled Development of Wind Power Generation

（1）Synchronous electric grid is an important guarantee for the large-scaled grid connection of wind power generation.

Interconnection of large electric grids is always the development trend of the electric grids in

the world. As time goes by, the synchronous electric grid also expands in scale. The electric grid interconnection in Europe has undergone the course from small scale to large scale, low voltage level to high voltage level, regional interconnection to large-scaled interconnection. The development history of European synchronous electric grid shows that transnational grid interconnection has brought about tremendous benefits to European countries, and synchronous electric grids have become an important guarantee for realizing the large-scaled grid connection of wind power generation in some European countries.

（2）Structure of power source is an important decisive factor for the capacity of absorbing wind power generation of the electric grid.

Nuclear power accounts for 16% of the installed capacity in Germany, with the coal-fired power generation accounting for 35%. Meanwhile, high-quality peak adjusting power sources such as natural gas, fuel oil and water-pumping energy storage power generation account for about 25% of the installed capacity. The hydraulic and biomass energy etc. that can be used as peak-adjusting power source account for 8%, while wind power generation accounts for 16%. Nuclear power may bear basic power load in the power system with such structure of power source, and coal-fired power generation may not basically participate in peak adjustment and may bear basic power load. The power-source structure of Germany has provided sufficient peak-adjusting capacity for the large-scaled grid connection of the wind power generation.

The accumulated installed capacity of wind power generation of Spain reached 19.15 million KW at the end of 2009, second only to those of America, Germany and China, ranking the 4th worldwide. Wind power generation accounts for over 20% of the installed capacity, and generate 14.3% of the generated power. The flexible means of power generation including hydraulic power generation, water-pumping energy-storing power generation, fuel gas power generation and combined circular power generating units in Spain account for 49.3% of the total installed capacity. The current capacity of water-pumping and energy-storing power generation is 4.80 million KW, accounting for 30% of the current installed capacity of wind power generation. And some projects are being built now, and the capacity thereof will be further increased. Meanwhile, the permitted operational scope of the combined circular power generating units is 50% of their capacity. The aforesaid flexible means of power generation have played an important role in the large-scaled grid connection of wind power generation.

（3）Accurate power prediction is an effective way for increasing the capacity of absorbing wind power generation of the electric grid.

At present, the power prediction system of wind power generation in Europe, America and Canada has become part of the power system, and has great significances for dispatching, operation of the power system, safety and stability of the electric grids, and improvement of the capacity of wind power generation into the electric grid. The uncertainty(prediction error) in power prediction of wind power generation inside the system has increased the demands for peak-adjusting capacity to be increased in the system. Therefore, improving the prediction accuracy of the power prediction system of wind power generation can effectively reduce the demands for increase in the capacity of peak-adjusting units of the system due to grid connection of wind power generation, which is of great economic significances. Power prediction of wind power generation is the first-choice technical method for solving peak adjustment after grid connection of wind power generation.

Spain's experience in realizing the large-scaled grid connection of wind power generation shows that accurate power prediction of wind power generation can effectively increase the capacity of absorbing wind power generation of the electric grid. At present, Spain has reached the level of controlling error below 30%(with average error no more than 20%) for prediction made 48 hours in advance and 15%(with the average error no more than 10%) for prediction made 24 hours in advance.

（4）Dispatching operation in a larger area or market is the optimized choice for reducing the influences on the electric grids and the grid-connection cost.

Transnational dispatching and transaction of wind power generation inside the whole EU will substantially improve the overall capacity of absorbing wind power generation. As shown in the report on the analysis of the output power probability of wind power generation of 200-million installed capacity of wind power generation in EU in 2020, if extensive wind power dispatching is carried out through transnational electric grids inside EU, the average wind power capacity credit will be increased from 7% in case of independent dispatching and absorption of wind power generation by various countries to the current 14%.

At present, there are about 140 balanced areas in America. And each balanced area adjusts the balance between load and power generation on its own inside the area, and meet the requirements of NERC. In 2004, the largest power company Xcel Energy studied the wind power penetration rate of 15%(equal to 12% of the electric quantities). As for single controlled area, the grid connection cost of wind power generation is about $4.60/MWh； Grid connection study was carried out in all the controlled areas of the state in 2006, and the penetration rate of the wind power generation was equal to 25% of the electric quantities, while the grid connection cost was $4.41/MWh. Meanwhile, as shown in the independent analysis by New York State, compared with balance inside the state, balance inside a single balanced area shows greater changes within 1 hour, 5 minutes and 6 seconds.

（5）Distributed means of wind power development is beneficial to grid connection of wind power generation.

Development of land wind power generation is Germany and Denmark etc. is basically distributed, and the geographic distribution of the installed capacity of wind power generation has effectively smoothed out the fluctuations in output power of various wind farms and wind power generating units, and can activate the peak-adjusting resources of the power system in a larger scope, which is also beneficial to the local absorption of wind power generation.

（6）Strengthening power market management and formulation of economic incentive policies are important guarantee for improving the capacity of absorbing wind power generation of the electric grids.

The leading countries in Europe and America in terms of wind power generation has paid greater attention to power market management and economic incentive policies in addition to promoting and applying power prediction techniques for wind farms and the technical standards for grid connection of wind farms and wind power generating units to promote rational grid connection and dispatching of wind power generation, mainly including: expanding the scope of dispatching, subsidy for electric grid investment and cost-amortizing policy, "favorable price for high-quality" policy and market competition mechanism etc..

4. Proposal on Guarantee Measures for Solving Large-Scaled Grid Connection of Renewable Energy

Though China has basically established the policy framework that encourages renewable-energy power generation, the policies including power price, expenses amortization and financial and tax preferences etc. are mainly for regional objects such as equipment manufacturing and power source construction, and there is no policy measure specially for optimizing electric grid construction. And there is no mechanism encouraging, guiding and strengthening absorption of renewable power generation into the electric grids in the current policy system. For example, the power price of the fuel gas or water-pumping energy-storing power generation participating in peak adjustment, or formulation of access standards of power generating units friendly to electric grids, which has intensively tapped the technical potentials of various parties, and has given a full play to the initiatives of their own.

The principle of “purchase in full” emphasized in the “Renewable Energy Law” still faces many unsolvable technical difficulties in the operational aspect, while the further large-scaled development of renewable energy power generation will necessarily lead to adjustment of interest pattern. For example, interest guarantee for peak-adjusting power sources for wind power generation, cost accounting for long-distance transmission of wind power generation in the electric grids, and construction of power sources of flexible adjusting capacities etc.; Proper response shall be made to such issues before renewable energy power generation such as wind power generation step on the road of healthy and large-scaled development. According to the previous analysis, from the perspective of constructing ten-million KW wind power generation bases, merely emphasizing the social responsibilities of the electric grid enterprises is far from enough for promoting long-term wind power generation to play a great role in national social economy, and it is necessary to adopt various technical measures for promoting the large-scaled grid connection of wind power generation in technical aspect, and carry out fair and rational arrangement in the aspect of policy and system, dredge interest-conducting channels, guide corporate investment. Only in this way can development of wind power resources be guaranteed to the greatest extent.

4.1 Technical Aspect

4.1.1 Speed up deployment of short-term power forecasting techniques for wind power generating system, improve capacity of dispatching electric grids

Reference shall be made to the successful experience in promoting the large-scaled development of wind power generation with the wind power prediction in Europe, and regard wind power prediction as an important part of future power system construction based on the current work. Carry out relevant research as soon as possible, and constantly improve prediction accuracy, and reduce the demands for increase in peak-adjusting capacity of the system due to grid connection of wind power generation as much as possible so as to improve the economy of electric grid operation and the capacity of absorbing wind power generation of the electric grids.

Wind power prediction requires close cooperation between the wind power developers and electric grids etc.. The developers shall provide basic data for the electric grid company to carry out power prediction. The electric grid enterprises shall establish regional concentrated wind power prediction platform, carry out regional wind power prediction to provide technical support for

making out rational electric-grid dispatching plan.

In addition, in the long run, the electric grid department shall establish a special renewable energy dispatching organ to take charge of coordinating dispatch between wind power generation, solar power generation and other power sources based on the power prediction.

4.1.2 Make out perfect grid-connection technical standards, guide the industry to develop equipment that meet the requirements of the electric grids

As the market share of wind power generation keeps on expanding, the difficulties confronting absorption of wind power generation cannot be solved through simply depending on the own force of the electric grid side from the perspective of the optimized system. Instead, it is necessary to fully tap the technical potentials of various parties such as the manufacturers, wind farms and other supplementary power sources inside the electric grid. Especially, the current wind power generation manufacturing industry of China has made considerable progress, and has fully stridden over the phase of “technical introduction” to the phase of “joint design”. In addition, the state has assessed the time and situation and lifted the protective restriction of “localization rate of 70%” to promote the domestic industries to strengthen innovation and grow stronger. As the strengths of the domestic frequency conversion and controlling system manufacturers keep on becoming stronger, most of the leading wind power manufacturing enterprises have acquired strengths for carrying out further upgrading in grid-friendly techniques such as low-voltage transverse, active powerless control etc. during in-depth participation in joint design. In fact, the current fierce competition of wind power generating manufacturing industry also needs to guide the corporate innovation through making out certain technical requirements.

Therefore, it is necessary to carry out formulation of relevant technical standards and supplementary policy system, establish compulsory market entry system, guide the enterprises to pat attention to development of grid-friendly wind power techniques and constantly build up the core competitiveness of the enterprises. In addition, practical economic incentive measures shall be adopted to encourage enterprises to make innovation in this respect, and maintain the vitality of the domestic and local enterprises during the growth period.

4.1.3 Certain marginal electric quantities shall be permitted to be abandoned to lower the overall peak-adjusting demands and cost of the electric grids;

Thought “abandoning wind power” deviates from the principle of purchase in full in “Renewable Energy Law”, it is the necessary choice after determining the optimal value of “the installed capacity of power generation” from the perspectives of the system.

Of course, abandoning wind power shall have guarantee system. Firstly, it is necessary to study the rational proportion of abandoned wind power carefully. The areas of different load features and peak-adjusting capacities shall have different proportions of abandoned wind power. Secondly, it is necessary to make certain compensation for the abandoning of wind energy by the wind power developing enterprises. Thirdly, planning must be made for wind power construction in advance. Only after the overall layout of the wind power construction is made definite can the construction of the supplementary facilities of the electric grids guaranteed, and can the proportion of the abandoned wind power be lowered to the greatest extent.

4.1.4 Strengthen the construction of adjustable power sources and regional grid connection, strengthen system adjusting capacities

Though strengthening power prediction for wind power generation and improving the performance of wind power generating units etc. can improve the adaptability of wind power generation, compared with conventional power, such cannot change the random features of wind power output thoroughly. Therefore, it is advised to incorporate wind power generation into the relevant planning for electric grid construction, and make overall planning for the future national development thoughts on wind power, other power sources and electric grids, including increase the powerful strengths of the areas with concentrated wind power generation, pay attention to the layout and construction of adjustable power sources such as water-pumping energy-storing and fuel gas power generation etc.. Especially, make out planning and deployment of natural gas power generation as soon as possible, encourage production and application of thermal power generating equipment with in-depth adjusting capacity while strengthening liaison capacities of regional electric grids and increasing the overall adjusting capacities of the electric grid in a larger scope to adapt to the requirements of the large-scaled development of wind power generation and future photoelectric power generation.

4.1.5 Pay attention to and support development of distributed power sources while intensively developing resources;

The distribution of wind energy resources of China varies from that of Germany and Denmark, which lies in remote areas far away from the power loads with weak electric grid conditions, and requires means of intensive construction and long-distance power transmission for wind power generation. However, it is necessary to actively guide and encourage areas with inferior geographic conditions or unqualified for constructing large-scaled wind farms(for example, mountainous areas, river valleys and coastal islands etc.) to construct small-scaled wind farms, and consider the feasibility of the program for local absorption of wind power generation such as heat supply etc. so as to fully give play to the flexible advantages of the distributed development of power source, and speed up the development process of wind power sources in qualified areas. Consideration shall also be given to the coordinated development of photovoltaic power generation of urban buildings and desert power stations while constructing solar power generation.

4.1.6 Speed up development of new energy techniques such as energy storing techniques etc.;

The random features of the output power of wind power generation and solar energy cannot be changed completely, Storing intermittent energy through developing new energy techniques and then meet various energy demands(for example, drive electric automobiles) with flexibly adjustable capacities will be the major direction for technical development of future new energy techniques. At present, such new energy techniques still belong to frontier research fields in the world, and China shall pay attention to R&D, lay a solid foundation, make progress step by step consistently and carry out long-term accumulation of techniques and talents to realize technical breakthroughs at an earlier date while developing the current techniques.

4.2 System Aspect

4.2.1 Integrate administrative interference with policy incentives, and reach the development objectives in an economic and efficient way

In view of the differences in resources and development costs of the renewable energy among various regions, integrating administrative interference and policy incentives can give play to the market mechanism and value laws, promote solution of the contradictions due to the imbalanced renewable energy development among various regions. It is necessary to establish dual system of economic dispatching and physical dispatching for renewable-energy power generation, and establish the quota transaction system and dispatching compensation system for renewable energy. Listed transaction for sales and purchase of the on-grid quota indexes of the renewable energy power generation is permitted to carried out in various areas so as to realize the maximum economic benefits and minimize the cost and expenses based on realization of the overall objectives.

4.2.2 Implement relay dispatching, rationally distribute absorbing cost, and duly improve the local economic benefits

The electric grid enterprises are required to implement relay dispatching for the renewable energy power generation, and transmit as much renewable energy power generation as possible to the outside parties and make use of the differences in selling price of the power between various areas to digest transmission cost.

The electric grid enterprises shall rationally distribute the cost of absorbing renewable energy power, and it is necessary to implement whole-grid sharing system for the cost of the renewable energy power absorbed by various electric grids, uniformly incorporate construction of power facilities specially used for wind power and photoelectric transmission into construction cost accounting of the electric grids instead of separate accounting.

Duly increase the on-grid power price of renewable energy power generation, and 5-10% of the power price will be definitely the income of local finance. The part of the renewable energy power purchased in other areas shall be jointly owned by the two areas and distributed through negotiation.

4.2.3 Strengthen construction management for renewable power generation projects, and incorporate into construction planning of electric grids

Firstly, the state will make out definite and rational wind power generation planning, and make definite the key development areas for construction of wind power generation and solar power generation according to the requirements of national economic development , and the development objectives during the planning period of various areas so as to avoid unduly construction of wind power generation and solar power generation in areas with difficulties in grid connection, which may influence the practical investment benefits.

Secondly, make out scientific and rational electric grid construction planning according to the national renewable energy planning, and make arrangement in advance to provide technical support for the scaled development of renewable energy power generation.

Thirdly, the state shall make definite the power market for trans-regional wind power transmission based on wind power construction and electric grid planning, and coordinate the selling and purchase price of the power as well as plan the future large-scaled development pattern of wind power generation at an earlier date.

4.2.4 Establish interest dredging and guiding mechanism of the system, especially give play to the role of price lever

The current rules for determining power price and power dispatching have failed to fully embody the value of the installed capacity of power generation that can play different roles in safe operation of the electric grids. For example, peak adjusting and reserve equipment etc.; The value thereof is realized indirectly through power dispatching between the electric grid enterprises, which cannot activate the initiatives of the enterprises in participating in construction of such power source. There is still no price policy for power sources with flexible adjusting capacities, including natural gas and water-pumping energy-storing power stations now, and the capacity value thereof in the system cannot be effectively embodied.

On the other hand, from the perspective of the consumption end, there is currently no rational peak-valley price mechanism to guide power consumers, and the peak-valley difference of the load has not been lowered through promoting more economic power consumption for the system, which has indirectly increased the peak-adjusting pressure on the electric grid enterprises.

Therefore, it is necessary to give full play to the price lever of the government, activate the initiatives of various parties in market participation, and utilize differential power prices such as dual power prices etc. to guide and encourage enterprises to build up power sources with more flexible adjusting capacities, and increase the flexibility in grid dispatching. Meanwhile, it is necessary to apply peak-valley power prices etc. to guide the means of power consumption of the power consumers, encourage power consummation in non-peak periods and lower the pressure for peak adjustment on the electric grid enterprises.

4.2.5 Realize corresponding incentive measures in technical aspect

In addition to calling for equipment manufacturers, developers, electric grid enterprises and even peak-adjusting power source enterprises such as thermal power generation plants etc. to deeply tap own technical potentials, renewable energy power generation still belongs to a new industry now, and many new techniques cannot be applied rapidly. Therefore, it is necessary to guide and encourage enterprises to carry out R&D and application of such new techniques through certain incentive measures to increase the renewable energy power absorbed by the electric grid. For example, certain incentives shall be given at the beginning when guiding development of grid-friendly wind power generating units and techniques, introducing deeply-adjustable thermal power generating units, making short-term forecast of wind farms, and abandoning part of the marginal wind power on the wind farms to adapt to the power dispatching. And the enterprises shall be encouraged to make such investment and actions so reach the purpose of tapping their technical potentials as much as possible, and lowering the peak-adjusting pressure of the electric grid enterprises indirectly.

（四）Proposals on Guarantee Policies for Solving Large-Scaled Grid Connection of Renewable Energy

At present, China still generally lies in the initial phase of the scaled development of renewable energy, and the capacity of independent innovation is still being cultivated. In addition, the electric grid enterprises have limited experience in absorbing renewable energy. According to the prior analysis, it is necessary to make definite the main direction for promoting development of renewable energy from the perspectives of the promoting the national scaled development of grid connection of renewable energy. And fair and rational arrangement shall also be made in policy and system while dredging interest conducting channels, guiding corporate investment so as to guarantee development of renewable energy resources to the greatest extent.

As for technical aspect, firstly, it is proposed to carry out R&D and popularize and apply advanced and reliable short-term forecasting techniques for renewable energy as soon as possible and improve the dispatching capacity of the electric grids. Secondly, it is proposed to make out technical standards for grid connection of renewable energy power generating units to guide industrial development of renewable energy to adapt to the techniques that meet the requirements of the electric grids. Thirdly, it is proposed that the marginal renewable energy power under extreme conditions shall be permitted to be abandoned to improve the overall peak-adjusting capacity of the electric grids. Fourthly, it is proposed to strengthen construction of power facilities with adjusting capacities and connection of regional electric grids and strengthen the overall adjusting capacities of the electric grids. Fifthly, pay attention to and support development of distributed wind power generation together with intensive energy development. Sixthly, it is proposed to speed up development of new energy techniques such as energy storing techniques.

As for system, firstly, integrate administrative interference with policy incentives, and reach development objectives in an economic way; Secondly, rationally distribute absorbing cost and duly increase the local economic benefits. Thirdly, strengthen construction management of renewable energy projects, and incorporate construction of renewable energy into construction and planning of the electric grids. Fourthly, establish interest dredging and guiding mechanism of the system. Fifthly, give play to the role of price lever, and guide and encourage participation by various parties. Sixthly, establish corresponding incentive measures for realizing the technical measures.